

Domain decomposition on mosaics

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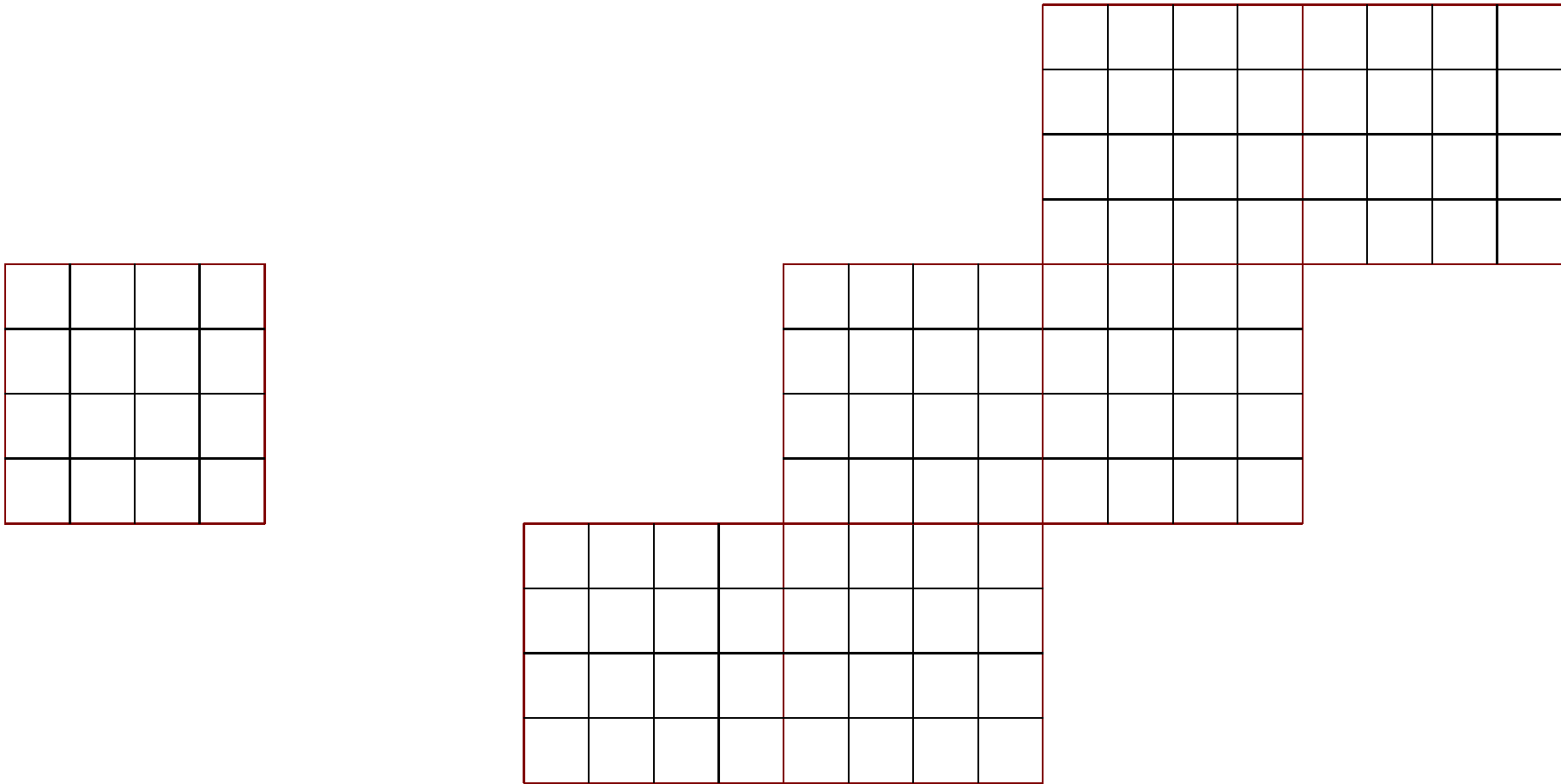
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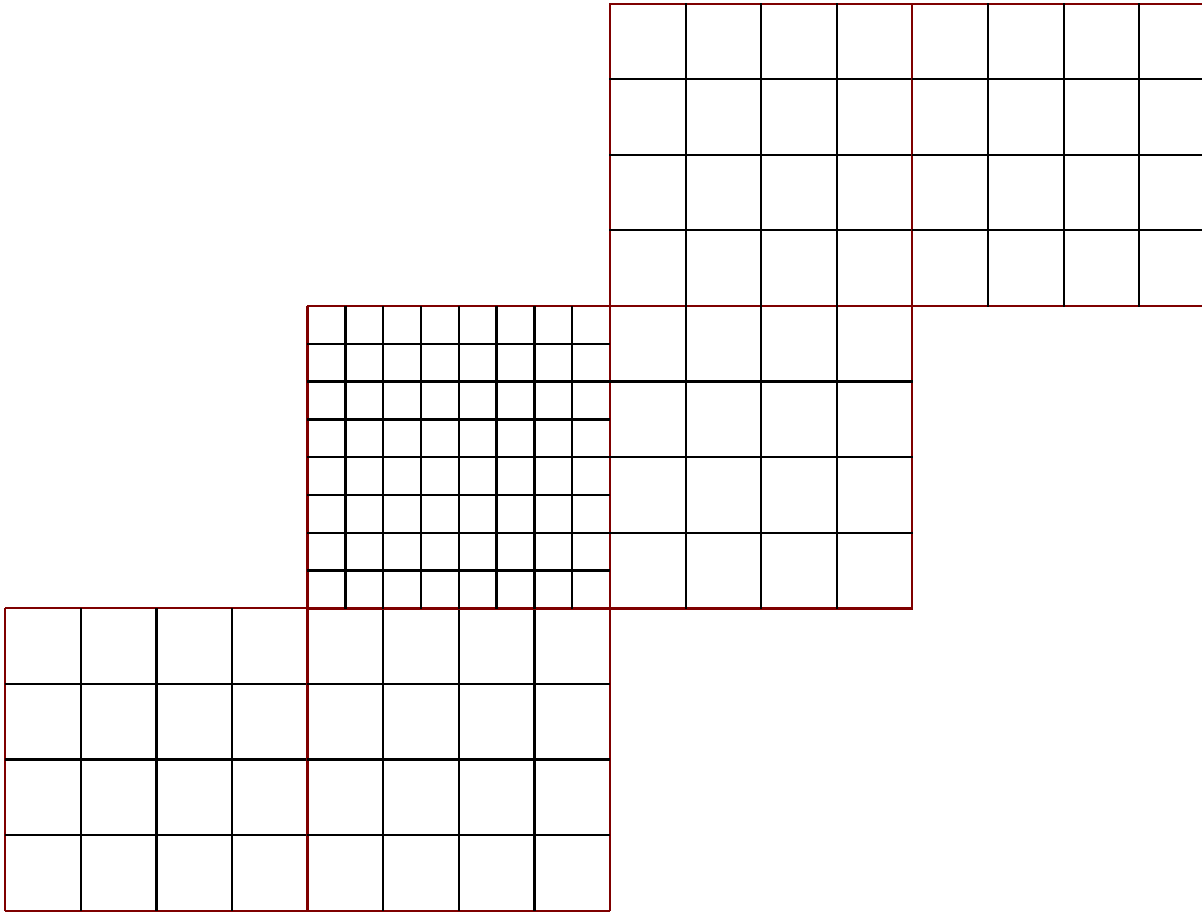
What is a mosaic?



We restrict ourselves to logically rectangular grids (LRGs), in which horizontal index space can be represented by the pair (i, j) . The physical coordinates could be curvilinear.

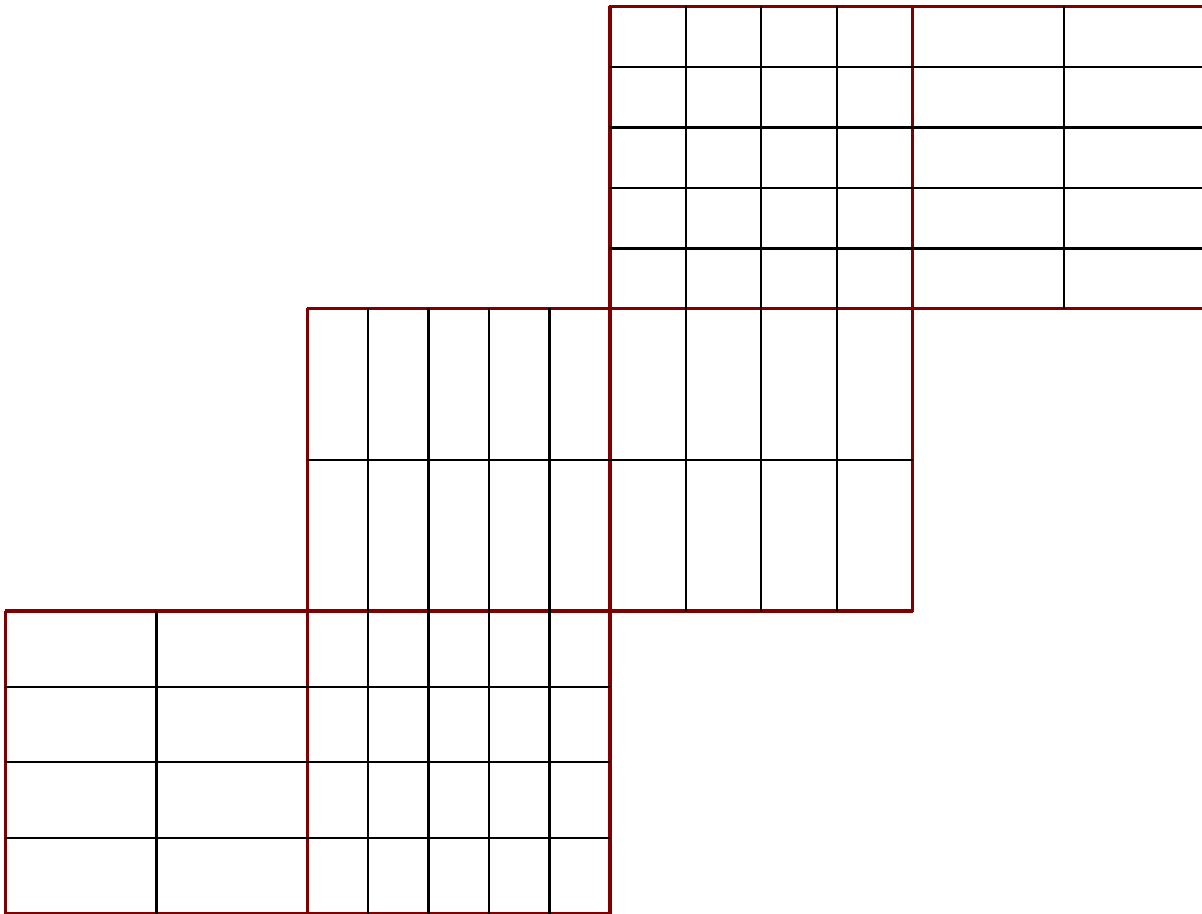
On the left is a basic 4×4 **tile**; on the right a grid composed of a mosaic of such tiles. This is a **continuous grid**.

Refined grids



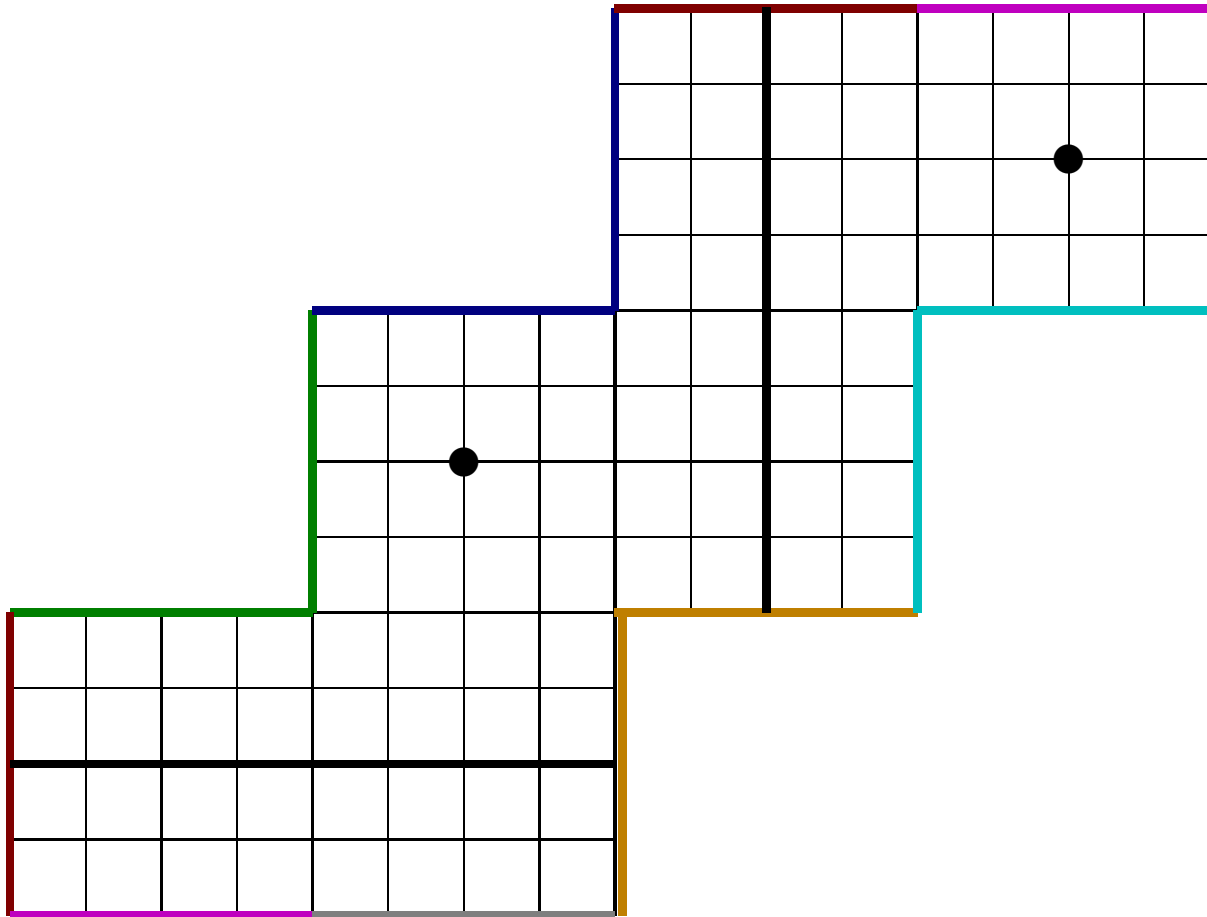
- A **refined grid** is where the continuity condition above is violated: where some tiles in the mosaic have more or fewer grid lines than neighbouring tiles with whom they share boundaries.

Uneven continuous grids



A mosaic need not have even resolution to satisfy continuity. This mosaic is composed of tiles of resolution 2×4 , 5×4 , 5×2 , 4×2 , 4×5 , 2×5 , but all grid lines are continuous.

Cubed sphere



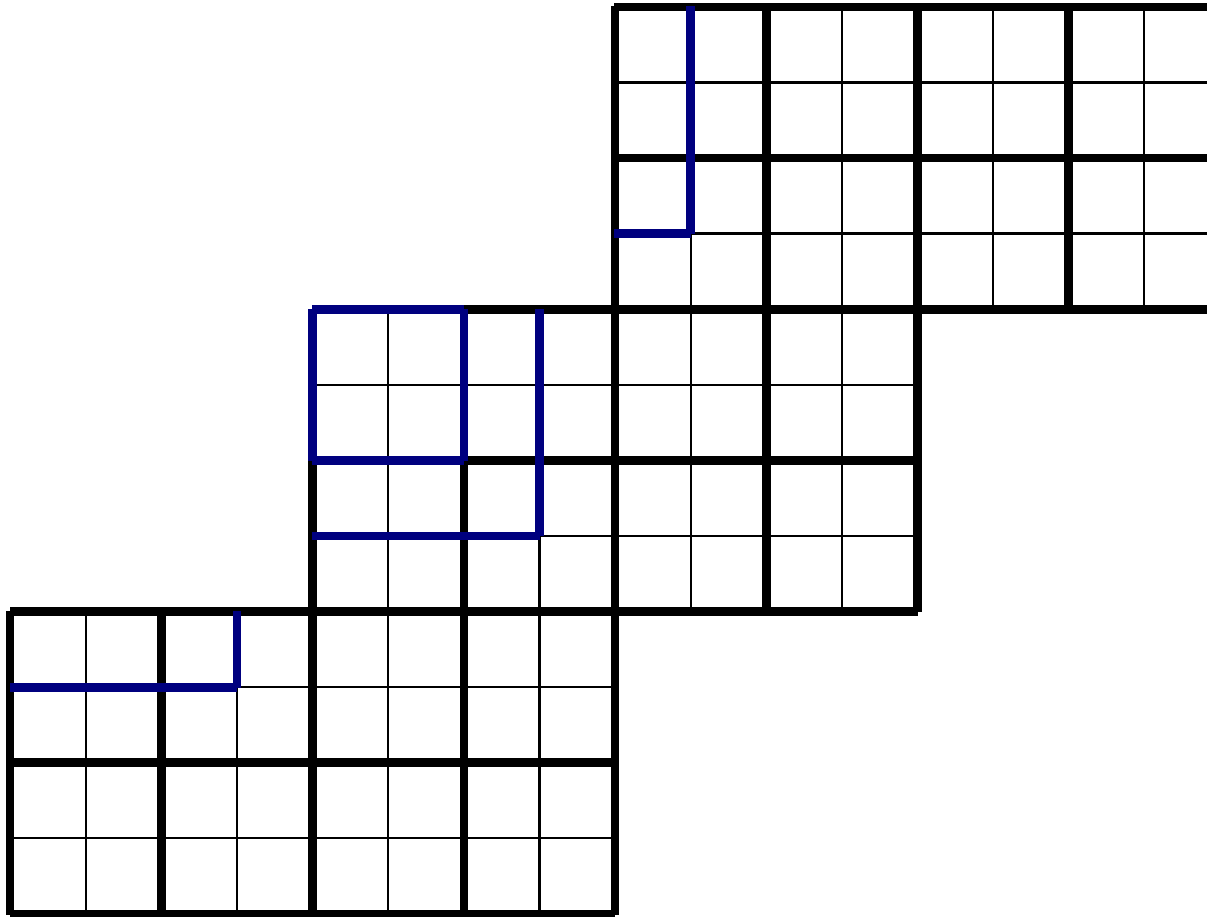
Mosaic topology for the cubed sphere. Note that boundaries may change orientation: the point just to the “west” of (5,6) is in fact (3,4); and furthermore vector quantities transiting the boundary at that point will undergo rotation.

Parallel decomposition of a mosaic

This is done in two steps:

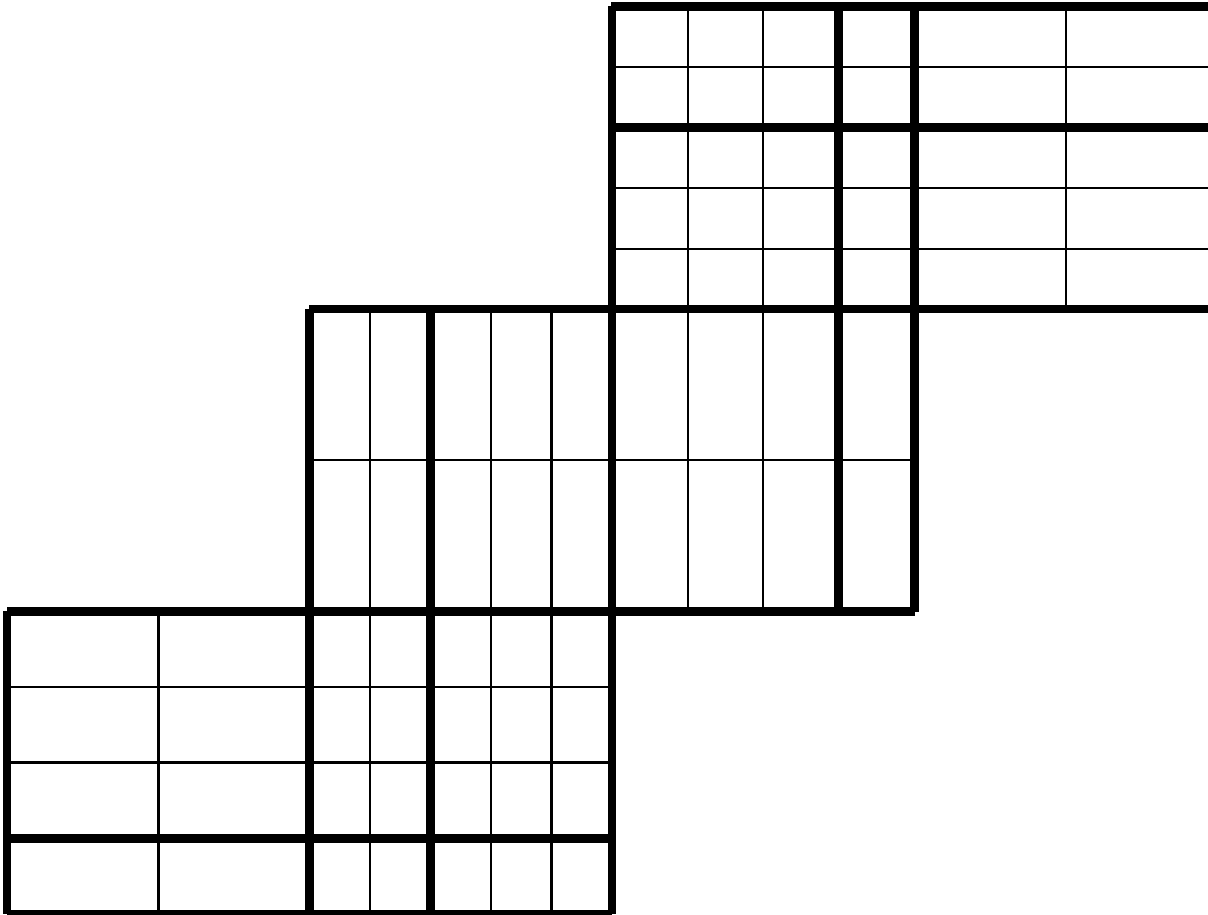
1. Each tile in the mosaic is assigned to a distinct **PElist**.
2. A normal 2D decomposition is applied to the tile.
 - The first, and key advantage of this approach is that **arrays need not be indexed by tile number**. Existing code using **(i,j)** and **(i,j,k)** arrays can be used with no transformation.
 - The second advantage follows from the use of a **continuous decomposition**, defined in the same spirit as a continuous grid.

Continuous decomposition



The domain boundaries of this decomposition follow continuous grid lines. Halo dependencies on a mosaic are structured similarly to the conventional domain decomposition of a single tile, with boundary halos and corner halos each coming from a single domain. (The “northwest halo” is missing for the cube topology.)

Uneven grids can have continuous decomposition



Continuous decompositions do not imply domains of even size.

Advantages of continuous decompositions

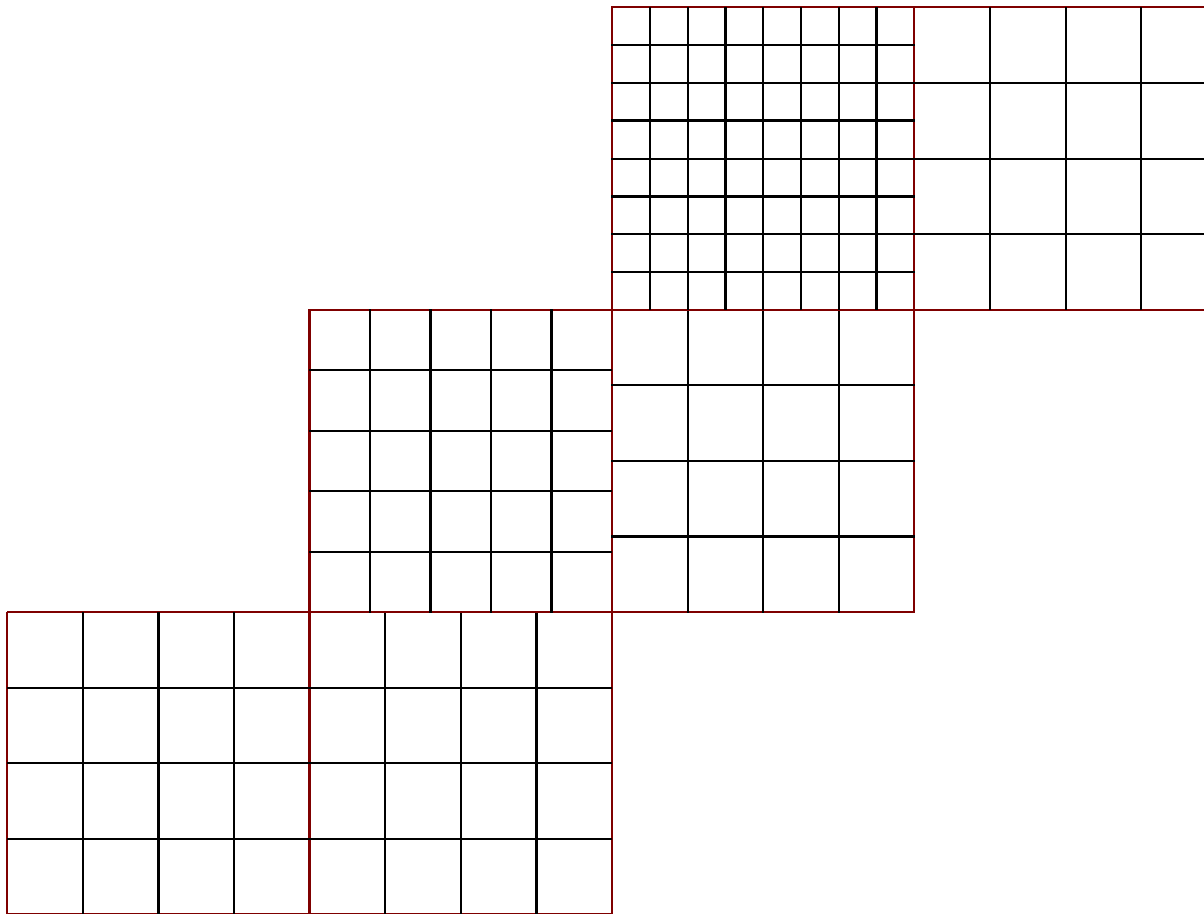
- Continuous decompositions on a mosaic can be very rapidly implemented in current domain software (MPP Domains and ESMF), since they precisely follow the “4 sides and 4 corners” or “NEWS” structure.
- A constant global index space independent of parallel decomposition is one of the features of MPP. We can maintain it for any mosaic of a continuous grid, since it may be inscribed in a bounding rectangle.

Refined grid considerations

We propose the following design for refined grids:

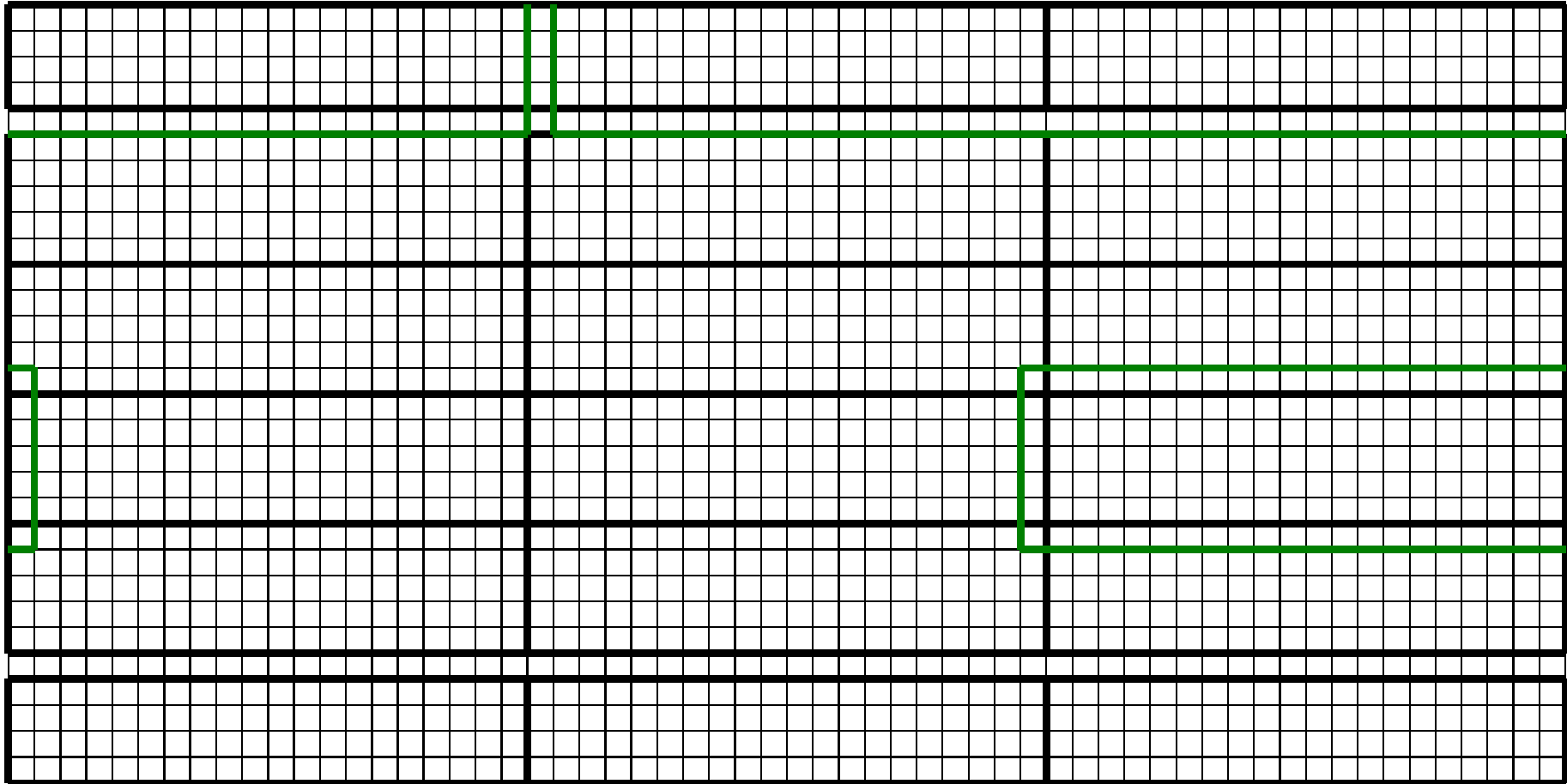
- The tile of the mosaic which contains a refined grid will also define another underlying grid which preserves continuity over the entire mosaic. This is needed so that software dealing with data dependencies and communication (i.e data movement only, and no arithmetic) can be kept separate from the interpolation and averaging software. When a halo update or other communication is performed, it will take place on the underlying continuous grid (which is required to have a continuous decomposition) and may cross tile boundaries. The exchange between the continuous grid and the refined grid is a separate step, and takes place within a tile.
- It is probably a good idea every grid line of the underlying continuous grid also be a line of the refined grid. We call this **true** refinement. This can allow all averaging and interpolation to be processor local.
- The underlying continuous grid is only used for data movement: all numerical kernels can work entirely on the refined grid directly.

“True” refinement



The tile at $(8,8)$ shows *true* refinement; the tile at $(4,4)$ does not.

Using a mosaic to make uneven halos



Domains near the poles are given halos spanning the whole latitude circle.

Summary

- The FV core stands to benefit from a rapid deployment of a **Mosaic** extension to current domain update technology (FMS-MPP and ESMF).
- The **Mosaic** extension will initially implement a *continuous* decomposition. Continuous decompositions can be applied to many logically rectangular mosaics, including in the context of nested grids, adaptive grids, reduced grids, and cubed-sphere, geodesic, or other tilings of the sphere by quadrilaterals. Grids with true refinement are covered by continuous decompositions, but possibly not in a load-balanced way.
- Discontinuous decompositions need a somewhat longer development cycle.
- The **Mosaic** extension will initially be used to apply a 2D *XY*-decomposition to the current FV core on a standard lat-lon grid; but will also support rapid development of the cubed-sphere or other novel grids.